CLAIMS

What is claimed is:

1. A method for chemical mechanical planarization of a work piece having a ruthenium layer thereon, the method comprising the steps of:

polishing the ruthenium layer using a low contact pressure;

exposing the ruthenium layer to a planarization composition concurrently with said step of polishing, said planarization composition comprising a dispersing medium and a plurality of abrasive particles and having a composition pH; and

removing the ruthenium of the ruthenium layer as a ruthenium hydroxide if said composition pH is in the range of from about 8 to about 12.

2. The method of claim 1, said planarization composition further comprising an oxidizing agent, and the method further comprising removing the ruthenium of the ruthenium layer as one of a ruthenium oxide and a hydrated ruthenium oxide if said composition pH is in the range of from about 2.5 to about 14.

3. The method of claim 1, said planarization composition further comprising an oxidizing agent and a complexing agent, and the method further comprising transforming the ruthenium of the ruthenium layer to an ionic state and removing the ruthenium as a ruthenium complex if said composition pH is no greater than 2.5.

4. The method of claim 1, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition comprising a plurality of abrasive particles having a Mohs hardness in the range of from about 5 to about 9.

5. The method of claim 4, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition having a plurality of abrasive particles formed from at least one material selected from the group comprising silica, alumina, zirconia, and titania.

6. The method of claim 1, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition comprising a plurality of abrasive particles having a particle size in the range of about 20 nm to about 2 microns.

7. The method of claim 2, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition comprising a plurality of abrasive particles having a Mohs hardness in the range of from about 5 to about 9.

8. The method of claim 7, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition having a plurality of abrasive particles formed from at least one material selected from the group comprising silica, alumina, zirconia, and titania.

9. The method of claim 2, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition comprising a plurality of abrasive particles having a particle size in the range of about 20 nm to about 2 microns.

10. The method of claim 2, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition having an oxidizing agent selected from the group comprising hydrogen peroxide, peroxysulfuric acid, periodic acid, monopersulfates, dipersulfates, and di-tert-butyl peroxide.

11. The method of claim 3, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition comprising a plurality of abrasive particles having a Mohs hardness in the range of from about 5 to about 9.

12. The method of claim 3, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition having a plurality of abrasive particles formed from at least one material selected from the group comprising silica, alumina, zirconia, and titania.

13. The method of claim 3, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition comprising a plurality of abrasive particles having a particle size in the range of about 20 nm to about 2 microns.

14. The method of claim 3, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition having an oxidizing agent selected from the group comprising hydrogen peroxide, peroxysulfuric acid, periodic acid, monopersulfates, dipersulfates, and di-tert-butyl peroxide.

15. The method of claim 3, wherein said step of exposing comprises exposing the ruthenium layer to said planarizing composition having a complexing agent selected from the group comprising L-2-amino-3-hydroxybutanoic acid (threonine, $C_4H_9NO_3$), iminodiacetic acid (IDA, $C_4H_7NO_4$), N-(2-hydroxyethyl)ethylenedinitrilotriacetic acid (HEDTA, $C_{10}H_{18}N_2O_7$), ethylenedinitrilotetraacetic acid (EDTA, $C_{10}H_{16}N_2O_8$), DL-(methylethylene)dinitrilotetraacetic acid (PDTA, $C_{11}H_{18}N_2O_8$), trans-1,2-cyclohexylenedinitrilotetraacetic acid (CDTA, $C_{14}H_{22}N_2O_8$), diethylenetrinitrilopentaacetic acid (DTPA, $C_{14}H_{23}N_3O_{10}$), ethylenediamine ($C_2H_8N_2$), 1,2-dihydroxybenzene-3,5-disulfonic acid (Tiron, $C_6H_6O_8S_2$), 1-nitroso-2-naphthol-3,6-disulfonic acid (Nitroso-R acid, $C_{10}H_7NO_8S_2$), 1,2-di(2-oxole)ethane-1,2-dione dioxime (alpha-Furil dioxime, $C_{10}H_8N_2O_4$), thiocarbamide (Thioura, CH_4N_2S), thiosemicarbazide (CH_5N_3S), dithiooxamide ($C_2H_4N_2S_2$), hydroxide ion (OH^-), hydrogen thiocyanate (thiocyanic acid, CHNS), ammonia (NH_3), hydrogen nitrite (Nitrous acid, HNO_2), hydrogen sulfate ion (sulfuric acid, HSO_4^-), 2-hydroxyphenylpropenoic acid (o-coumaric acid, $C_9H_8O_3$), and 4-phenylthiosemicarbazide ($C_7H_9N_3S$).

16. The method of claim 1, wherein the work piece has an insulating layer underlying the ruthenium layer and the method further comprises the step of planarizing said insulating layer after the step of removing the ruthenium.

17. The method of claim 16, wherein the method further comprises exposing said insulating layer to said planarization composition concurrently with said step of planarizing said insulating layer.

18. The method of claim 2, wherein the work piece has an insulating layer underlying the ruthenium layer and the method further comprises the step of planarizing said insulating layer after the step of removing the ruthenium.

19. The method of claim 18, wherein the method further comprises exposing said insulating layer to said planarization composition concurrently with said step of planarizing said insulating layer.

20. The method of claim 3, wherein the work piece has an insulating layer underlying the ruthenium layer and the method further comprises the step of planarizing said insulating layer after the step of removing the ruthenium.

21. The method of claim 20, wherein the method further comprises exposing said insulating layer to said planarization composition concurrently with said step of planarizing said insulating layer.

22. The method of claim 1, wherein the work piece has a metal layer overlying the ruthenium layer and an insulating layer underlying the ruthenium layer and the method further comprises the step of planarizing said metal layer before the step of polishing the ruthenium and the step of planarizing said insulating layer after the step of removing the ruthenium.

23. The method of claim 22, wherein the method further comprises the step of exposing said metal layer to said planarization composition concurrently with said step of planarizing said metal layer and the step of exposing said insulating layer to said planarization composition concurrently with said step of planarizing said insulating layer.

24. The method of claim 22, wherein the steps of planarizing said metal layer, removing the ruthenium and planarizing said insulating layer result in a planarization selectivity of 1:1:1.

25. The method of claim 2, wherein the work piece has a metal layer overlying the ruthenium layer and an insulating layer underlying the ruthenium layer and the method further comprises the step of planarizing said metal layer before the step of polishing the ruthenium and the step of planarizing said insulating layer after the step of removing the ruthenium.

26. The method of claim 25, wherein the method further comprises exposing said metal layer to said planarization composition concurrently with said step of planarizing said metal layer and the step of exposing said insulating layer to said planarization composition concurrently with said step of planarizing said insulating layer.

27. The method of claim 25, wherein the steps of planarizing said metal layer, removing the ruthenium and planarizing said insulating layer result in a planarization selectivity of 1:1:1.

28. The method of claim 3, wherein the work piece has a metal layer overlying the ruthenium layer and an insulating layer underlying the ruthenium layer and the method further comprises the step of planarizing said metal layer before the step of polishing the ruthenium and the step of planarizing said insulating layer after the step of removing the ruthenium.

29. The method of claim 28, wherein the method further comprises exposing said metal layer to said planarization composition concurrently with said step of planarizing said metal layer and the step of exposing said insulating layer to said planarization composition concurrently with said step of planarizing said insulating layer.

30. The method of claim 25, wherein the steps of planarizing said metal layer, removing the ruthenium and planarizing said insulating layer result in a planarization selectivity of 1:1:1.

31. A planarization composition for chemical mechanical planarization using low contact pressures to remove ruthenium from a work piece, the composition comprising:

a dispersing medium; and

a plurality of abrasive particles dispersed in said dispersing medium, said abrasive particles having a Mohs hardness in the range of about 5 to about 9 and a particle size in the range of about 20 nm to about 2 microns, said plurality of abrasive particles comprising about 1 to 50 wt. percent of the composition;

wherein said planarization composition has a pH in the range of about 8 to about 12 and wherein said planarization composition causes the ruthenium to be removed from the work piece as a ruthenium hydroxide.

32. The planarization composition of claim 31, wherein said plurality of abrasive particles are formed from at least one material selected from the group comprising silica, alumina, zirconia, and titania.

33. A planarization composition for chemical mechanical planarization using low contact pressures to remove ruthenium from a work piece, the composition comprising:

a dispersing medium;

a plurality of abrasive particles dispersed in said dispersing medium, wherein said abrasive particles having a Mohs hardness in the range of about 5 to about 9 and a particle size in the range of about 20 nm to about 2 microns, and wherein said plurality of abrasive particles comprising about 1 to 50 wt. percent of the composition; and

an oxidizing agent;

wherein said planarization composition causes the ruthenium to be removed from the work piece as a ruthenium oxide when said planarization composition has a pH in the range of about 2.5 to about 14.

34. The planarization composition of claim 33, wherein said plurality of abrasive particles is formed from at least one material selected from the group comprising silica, alumina, zirconia, and titania.

35. The planarization composition of claim 33, wherein said oxidizing agent is selected from the group comprising hydrogen peroxide, peroxysulfuric acid, periodic acid, monopersulfates, dipersulfates, and di-tert-butyl peroxide.

36. A planarization composition for chemical mechanical planarization using low contact pressures to remove ruthenium from a work piece, the composition comprising:

a dispersing medium;

a plurality of abrasive particles colloidally dispersed in said dispersing medium, wherein said abrasive particles having a Mohs hardness in the range of about 5 to about 9 and a particle size in the range of about 20 nm to about 2 microns, and wherein said plurality of abrasive particles comprising about 1 to 50 wt. percent of the composition;

an oxidizing agent; and

a complexing agent,

wherein said planarization composition causes the ruthenium to be transformed to an ionic state and the ionic ruthenium to be removed as a ruthenium complex when the planarization composition has a pH no greater than about 2.5.

37. The planarization composition of claim 36, wherein said plurality of abrasive particles is formed from at least one material selected from the group comprising silica, alumina, zirconia, and titania.

38. The planarization composition of claim 36, wherein said oxidizing agent is selected from the group comprising hydrogen peroxide, peroxysulfuric acid, periodic acid, monopersulfates, dipersulfates, and di-tert-butyl peroxide.

39. The planarization composition of claim 36, wherein said step complexing agent selected from the group comprising L-2-amino-3-hydroxybutanoic acid (threonine, $C_4H_9NO_3$), iminodiacetic acid (IDA, $C_4H_7NO_4$), N-(2-hydroxyethyl)ethylene-dinitrilotriacetic acid (HEDTA, $C_{10}H_{18}N_2O_7$), ethylenedinitrilo-tetraacetic acid (EDTA, $C_{10}H_{16}N_2O_8$), DL-(methylethylene)dinitrilotetraacetic acid (PDTA, $C_{11}H_{18}N_2O_8$), trans-1,2-cyclohexylenedinitrilotetraacetic acid (CDTA, $C_{14}H_{22}N_2O_8$), diethylenetrinitrilopentaacetic acid (DTPA, $C_{14}H_{23}N_3O_{10}$), ethylenediamine ($C_2H_8N_2$), 1,2-dihydroxybenzene-3,5-disulfonic acid (Tiron, $C_6H_6O_8S_2$), 1-nitroso-2-naphthol-3,6-disulfonic acid (Nitroso-R acid, $C_{10}H_7NO_8S_2$), 1,2-di(2-oxole)ethane-1,2-dione dioxime (alpha-Furil dioxime, $C_{10}H_8N_2O_4$), thiocarbamide (Thioura, CH_4N_2S), thiosemicarbazide (CH_5N_3S), dithiooxamide ($C_2H_4N_2S_2$), hydroxide ion (OH^-), hydrogen thiocyanate (thiocyanic acid, CHNS), ammonia (NH_3), hydrogen nitrite (Nitrous acid, HNO_2), hydrogen sulfate ion (sulfuric acid, HSO_4^-), 2-hydroxyphenylpropenoic acid (o-coumaric acid, $C_9H_8O_3$), and 4-phenylthiosemicarbazide ($C_7H_9N_3S$).